Computer Agent's Role in Modeling an Online Math Help User

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ABSTRACT

This paper investigates perspectives of the deployment of the open learner model on mathematics online help sites. It proposes enhancing a regular human-to-human interaction with an involvement of a computer agent suitable for tracking users, checking their input and making useful suggestions. Such a design would provide the most support for the interlocutors while keeping the nature of the existing environment intact. Special considerations are given to peer-to-peer and expert-to-student mathematics online help that is free of charge and asynchronous. Examples from other collaborative, Web-based environments are also discussed. Suggestions for improving the existing architectures are given, based on the results of a number of studies on online learning systems.

Keywords: Mathematics Online Help, Computer Mediated Communication, Open Learner Model, Computer Agents.

1. INTRODUCTION

Progress in computer and communicational technologies during the last two decades has deeply affected our lives. The most profound effects are on young people who may not even remember life without cell phones, PDAs, laptops, or e-mail. Although schools try to keep up with some of these advances, for various reasons (cost, logistics, teacher training, …) they lag behind, which further increases the disconnect between in-school and out of school activities. In cases where schools incorporate modern technologies, it becomes obvious that these technologies ask for new pedagogies, which Balacheff and Kaput [2] emphasized saying that, "for teachers, traditional professional knowledge is not sufficient to deal with the deep changes in learning, teaching, and epistemological phenomena that are emerging" (p.495). Among important topics for future research, they included analysis of the complexity of the tutoring task in the context of telepresence and specification of the tools needed by the human distance tutor. Here the telepresence is related to telecomputing, a term used interchangeably with computer-mediated communication (CMC), which indicates using computers to communicate ([16]; [27]).

Descriptions of CMC made over the 5-8 year span do not do justice to changes that have happened in the meantime. According to Santoro [28], instructional CMC was primarily used for conferencing, informatics, and computer-assisted instruction. On Santoro's list of 13 uses of CMC the following seven – 1) mentoring, 2) guest lecturing, 3) public conferencing, 4) interactive chatting, 5) personal networking, 6) collaboration facilitating, and 7) peer review/counselling – are especially relevant since they involve direct peer-to-peer or teacher-student interaction, social binding, and creation of community. More recent categorization of *online learning* incorporates electronic mail, bulletin board systems, electronic whiteboards, inter relay chat rooms and desktop video conferencing [9]. Both descriptions come up short in terms of revealing the immense improvement in speed, access, cost, and features that presently exist in the educational World Wide Web.

Similarly, du Boulay and Luckin [8] address the influence of "networked technologies which allow learners to interact across widely distributed geographical locations," and ask:

> Are the issues which were pertinent to traditional face-to-face human teaching and learning still pertinent or should we be exploring the changes in human teaching within this paradigm in order to inform our designs for intelligent systems to support **this** learning? (p.19, emphasis added)

Garrison, Anderson and Archer ([12], p.7) warn that "the adoption of computer-mediated communication (CMC) in higher education has far outpaced our understanding of how this medium should best be used to promote higher-order learning." They view creation of a *critical online community of inquiry* in a text-based environment as a "major challenge facing educators using CMC." In such a community, activities like reflection and collaboration are used to discuss, question and challenge the assumptions. The problem that remains is how to organize, support and reliably assess the learning and functioning of such groups. Along these lines, Engelbrecht and Harding ([10], p.270) wrote that:

> The success of electronic communication in a mathematics learning environment has to be addressed. We need an articulation of the types and values of interaction: learner/content, learner/instructor, and learner/learner. We need an examination of what elements of human interaction might be lost and how that loss might be mitigated.

Here, we draw inspiration from the assertion that the "new technologies need new pedagogies" and the challenges put in front of educators to make online communication more beneficial for learning. It also makes sense to expect that the new pedagogies need to be supported by new technologies, thus making this process bidirectional, rather than unidirectional. Especially in the context of online tutoring, one wants the environment not to come in the way of the advantages tutoring has over regular classroom instruction. In order to tap into the most novel technological advances, this discussion paper addresses tutoring mathematics, CMC, and the design of hybrid learning environments with human tutor(s) and a computer agent. Specific emphasis is put on modeling a learner in an online environment through application of an open learner model incorporated into a "smart" network.

2. ONLINE LEARNING

Since its introduction in 1990s, the World Wide Web has supported human creativity and a new approach towards communal well-being. As a tool for CMC and a repository of a wealth of information it offers people the means to learn from previous work; to consult with peers and mentors at all stages of work; to explore, compose, and evaluate possible solutions; and to disseminate the results [32]**.** This cultural phenomenon has already produced results in the form of a number of sites where individuals and institutions offer their expertise and service without charge. Here we focus on mathematics help sites where expert or peer tutors answer questions online. Communication here is asynchronous, text-based, and service is provided on demand. Questions and answers are public and available for the review of all visitors to the site. Such sites are not related to any specific course and are usually designed as bulletin boards. Their main value is in the provision of educational environments where students take an active role in learning mathematics by setting up an agenda in the tutorial discourse or assisting their peers. Here, online educators have rare opportunity to learn the kind of questions students ask in a virtual space that affords "anonymity."[1] This sense of being anonymous that is present especially in cases when one does not have to register to the Web site, has a liberating effect on students who might otherwise be too restrained to fully engage with learning [24].

Indeed, the problem of the students not being fully engaged in the pedagogical discourse is well known. Brousseau [4] addressed the issue of the so called "didactic contract" which applies to both tutoring and teaching scenarios. Apparently, in those circumstances the students adapt by not relying only on mathematical knowledge, but also on knowledge of the teaching system, its norms and customs, and guesses about the expectations of the teacher. In other words, students sometimes ask questions not because they have a genuine interest or do not understand something, but because they are expected to. Such motivation is certainly not relevant for users of mathematics online help. Therefore, we take that the questions posted online are the consequences of the recognized bottlenecks in learning, genuine interest, or convenience of getting homework done.

However, this service is not without problems. As text-based, this environment is restrictive for mathematics discourse. From participants it demands sophistication in writing or interpreting mathematics text, skills in using hypertext, and patience while expecting a response. For various reasons that will be explained in the further text, it is not always successful. Therefore, we propose a hybrid model where a computer agent is involved thus making the communication more efficient and reliable while still providing for communal bonding and human-to-human assistance.

In the research community there is no unreserved agreement on pedagogical benefits brought by computer mediated communication. While the initial expectations were very optimistic, they were followed by a somewhat more realistic understanding that the universal panacea for education still eludes us. Engelbrecht and Harding ([10], p.267) are cautious in praising the use of asynchronous CMC for teaching, since it suffers from "the lack of immediate feedback, students not checking in often enough, the length of time necessary for discussion to mature and the sense of social disconnection experienced by students." They even claim that "the Internet is not a social-learning environment" (p.270), the notion supported by Noveck [25], who asserts that "the Internet provides for communities while encouraging atomization" (p.19). Furthermore, Noveck draws a parallel between the effect calculators have on arithmetic literacy, and the negative influence of the Internet on critical thinking and the "ability to translate information into knowledge" (p.25).

Other educators, however, emphasize the collaborative [18] component of the CMC which also encourages students to seek help [15] and empowers them to act as teachers. Rheingold (1993, as cited in [7]) stated that online communities are in part a response to the hunger for community that has followed the disintegration of traditional social groups around the world. De Vries, Bloemen and Roossink even "expect that online communities will become substitutes" for the traditional ones ([7], p.124).

CMC and Mathematics Help Sites

In view of the above principles, CMC opened new perspectives in mathematics education, especially by making available assistance to learners at distance. Mathematics online help sites that are discussed here, offer at least one of the following: (a) Use of a bulletin board for communication; (b) search through the database of previously asked questions; and (c) additional resources for learning. As a consequence, students operate in a simplified setting that is advantageous for inexperienced visitors. In order to find such sites students need to search the Internet using "math help" or "tutor math" as keywords. Furthermore, students need to be able to find the link to the appropriate mathematics discipline, utilize the bulletin board features, or browse through the documents on the Web site. See Table 1 for a summary of features available on four such sites.

Table 1

Available Features on Four Mathematics Help Sites

Main Form-Asynchronous				Options		
Web Site	Type	Archive	Features	Search	Other Resources	Synchronous
Ask Dr Math	Expert	Se-lected	Text-based	Keyword	Yes	No
Math Nerds	Expert	All	Text-based	Keyword	No	Yes
Math2	Peer	All	Text and Graphics	Keyword	No	No
Free Math Help	Peer	All	Text-based	Keyword	Yes	No

There are mathematics help sites that offer voluntary help from experts (tutors with certain credentials, experience in education, and a proven record of being able to answer mathematics questions successfully), as well as those that facilitate unsolicited help from the peers. Some sites feature both

[1] Here we use the concept of anonymity as perceived by the regular online user rather than what security experts would accept that this environment affords.

asynchronous and synchronous help. In some cases, apart from the bulletin board, the visitors to the site have available textbook-like examples and instructions, glossary of terms and even resources for teachers.

3. TUTORING ONLINE

This section contains a selection of findings related to how human tutors teach mathematics online and in which aspects expert and peer tutors' answering methods differ. The study (see [20]) was based on the content analysis of the student-tutor communication on the three purposely selected (peer; expert; peer & expert tutoring) help sites; and interviews and tutoring logs obtained from five expert tutors. The tutors were asked to keep logs of five threads of communication with the students. They had to categorize the question in some way they could find suitable; list and explain the word clues that caught their attention; and specify the information which was missing but would be useful to have. The tutors also had to describe the options they took into account before answering the question and explain why they chose the particular strategy.

The author concluded that the online expert mathematics tutors try to provide the right amount of help in the least amount of time and ensure that they really help the student. However, their knowledge of a student is limited, since they form a model of the learner based only on a message received from him/her. In the process of economizing with their time, expert tutors distinguish genuine interest or thirst for learning, from what they feel as abuse of this service. For example, if a student asks a specific question, like: "Solve 2*x-5=3," which may easily be a homework question, a tutor is likely to provide a hint, say: "Isolate your variable on the left side, move everything else to the right." However, if a student sends a general question of the type: "What is a graphical interpretation of a system of equations?" a tutor is more likely to provide thorough explanations and even some solved examples.

Expert tutors approach online communication with students holistically, thus noticing every little detail. They categorize: a) *questions* according to mathematical (e.g. disciplines, topics) or educational grounds (e.g. subject, level); b) *students* (e.g. naïve, ambitious, not interested in math, open for learning); c) *math problems* (e.g. intriguing); d) *communication* with a student (e.g. rare fit, unsuccessful); e) *a mathematics task* (e.g. beyond capability of the student); f) *student background* (e.g. unclear) and, g) *a problem solving history* (e.g. a student did some work).

The tutors expressed the need to know more about the a) background of the student (age, grade, subject,…); b) context in which the student was seeking this information (curiosity or assigned work); c) topics already familiar to the student (course/level); d) type of assignment (homework, term assignment); e) nature of the problem the student has (conceptual understanding or inability to apply procedures); f) depth to which the student went in solving a mathematics problem; g) strategies/pathways the student attempted before asking for help; and, h) as much of the student's actual work on the problem (to diagnose errors and misconceptions).

Since online communication may take too long to unfold, the tutors cannot be sure that the student who posted the question will still be interested in reading an answer, nor in participating in long exchanges of messages. For those reasons, they may be more helpful to students who appear inexperienced or unmotivated. There are other expert tutors' behaviours that emerge from their individual experiences and beliefs as educators. Such are more difficult to generalize. For example, if there are many ways to answer the question and a student model is too weak to influence the answer, some tutors may provide general instructions without details, while others would rather probe a student further than risk confusing the student even more by answering inappropriately.

Interviews with five expert tutors from the two Web sites pointed to the following:

a) It is difficult to keep being enthusiastic about this service since they (tutors) often do not even know if their answer was received, not to mention how helpful it was.
b) Tutors struggle with a *conflict of interest* in terms of how much help to provide without jeopardising the school assessment methods.
c) Tutors struggle with lacking appropriate model of a learner (background info, feedback from the student, etc.).

The tutors also complained about:

a) Having to answer mainly low level or shallow questions.
b) Students posting questions without first checking if similar questions have already been answered and if they are already available in the archives.
c) Students having difficulties writing math texts which end up being fragmented or erroneous, and thus challenging to decipher by the tutors.
d) Students not differentiating between math disciplines and therefore tutors receiving or picking the questions they may not be familiar with.

When asked to describe what success is for them in this type of communication, four out of five tutors stated that they measure success in tutoring by getting a positive feedback from a student. These experts further asked for a friendlier environment (more suitable for mathematics communication) and a quickening of the tutoring process.

Although the stated conclusions and recommendations, because of the small sample of the interviewed tutors, seem hardly generalizable, in the context of the whole study (triangulated with other available data) they appear relevant and plausible. Having this in mind, we turn to the online environments that incorporate intelligent computer programs equipped to assist, empower, and at times, replace the humans.

4. INTRODUCING A COMPUTER AGENT

The approach that we take here comes from the realization, also expressed by other researchers and practitioners in the field, that for the educational system to be successful, it is necessary that it acknowledges the learning differences and adapts to the individual needs of the learners. This notion almost contradicts the authors ([26]; [22]; [33]), who found that human tutors often have prepared in advance the so called, "curriculum scripts" – established routines in teaching the skills and concepts students are expected to master; and yet, the benefits of the face-to-face tutoring are well known. Apparently, the tutors follow the scripts, but they also fine-tune their behavior towards the student by taking into account many factors including the student's cognitive and emotional state; misconceptions; ability; and other ([11]; [19]; [6]).

In an attempt to simulate human tutors' success, Intelligent Tutoring Systems (ITSs) emerged from the application of Artificial Intelligence methods in the computer-assisted instruction (CAI). The ITSs used two basic strategies: One to diagnose and repair the student's misconceptions; while in the other, students had to follow the tutor's model [34]. Conceptually, even nowadays two basic models of ITSs remain: Procedural — where the system observes the steps taken by the learner and looks for errors or omissions to do remediation; and Product-based — where it only checks the final result against the known constraints in order to infer about the student's cognitive needs [17]. In 1993, Milech, Kirsner and Waters [23] stated that ITSs were relatively good at passing on knowledge, but were poor at teaching how to use the knowledge. Then again, even such ITSs were still more likely to teach optimal knowledge than other computer tutoring systems.

Since that time many changes happened in the field, one being the introduction of an "open model," the feature that enables the person whose background information is tracked by the system to have an insight into it. Other more recent advances are related to ITSs serving as pedagogical agents that can even be animated to best match the students' perceptions of advisor, motivator or helper [3]. Besides, ITSs assist students to "acquire domain-specific skills, but also [to] develop general help-seeking strategies" ([1], p.101). Bringing ITSs into the course-based or institution-based ("constrained") online environment is another contribution to the field. There, ITSs enhance common, albeit virtual space where learners "gather" and help them reach their cognitive and social goals.

In an analysis of the intelligent tutoring system (ITS) that supports such virtual community, Hansen and McCalla [14] discuss the issue of having an open model of the learner as well as the helper. This benefits both of them since the user can choose the best helper, while the helper can customize the response to the user. In such a case,

> [T]he user could be playing a number of different roles, such as a learner, a teaching assistant (TA), or perhaps an instructor. This role, if determined, helps to discover the learner's purpose and provides context to open the model. Each user plays different roles at different times, and may be playing more than one role at once. (p.250)

Open User Model in Online Math Help

Online help sites could also be improved by the introduction of intelligent automated components. This would, to some extent, diminish the problem of a weak student model, which is characteristic for this setup as participants do not know each other and seldom communicate, mostly through short exchanges. Those users who take *multiple roles* would be especially interesting since the temporal model would show when the student (*helpee*) *changed the role* to being a tutor (*helper*). This event can point to an increase in the student's confidence and his/her improved attitude towards mathematics. The opposite event of changing a role from a tutor to a student would not mean a decrease in confidence per se and should be determined on a case basis.

The problem with bulletin boards is that they are linear in nature, with postings intermingled in such a way that it may be difficult to determine who is responding to whom and in what capacity. On the peer tutoring sites, there are cases where one person answers somebody's question and somewhere in the same thread starts asking questions. Sometimes the person who asks a question also answers it later, thus making the tracking of communication complex. Even more, a tutor can post a comment to another tutor's posting as well as to a student's. Also, comments can be addressed to more than one person as in: "You are all wrong/right."

However, a) the complexity of the semantic analysis of natural and mathematics language and b) the fact that, contrary to expert tutors, peer tutors are not concerned with forming a model of the students [20], both provide incentives for simplistic design. Peer tutoring sites have a short response time and high throughput. Furthermore, peer tutors appear forgiving toward syntax errors in messages or inconsistencies in questions–they answer questions anyway [20]. In other words, online peer-to-peer mathematics help communities could benefit from the model proposed by Hansen and McCalla [14] as an optional add-on component provided to visitors to the site (e.g., "Find the best match for help."; "See who else is available.").

Self ([30], p.4) cautioned that "ITS philosophy is in danger of being regarded as obsolete," if its developers do not take into account that 20th century educational philosophy abandoned the model of transmitted knowledge in favor of knowledge growth. Among else, Self proposed that instead of Intelligent Tutoring Systems guessing a model of a student, they let the students provide information about themselves ([31], p.6). Online help is precisely the place where some kind of self-modeling might provide important extra information about a student. Both students and tutors can beforehand "introduce" themselves by selecting attributes provided by the system that can be later accompanied by the further developed "track record."

There are a number of avenues this process may take. One is a human-computer tutoring model where the computer agent does preliminary but optional screening. Although many users may feel intimidated by being forced to communicate with an agent before their question is sent to a human tutor, with a wider spread of human-computer interaction, the public will become more used to it and start accepting it better.

The agent can be of further assistance in several instances, including:

<u>Syntax screening.</u> Mathematics formulas that are inputted may not be clear or complete. The system can do initial syntax analysis and provide its interpretation of the question for the learner's approval.

<u>Problems clarifying.</u> This serves to help learners reflect and tutors create a more accurate model of the learner. There are two parts to it:

1. *Creating a communal knowledge base.* This is much more than the usual collection of links to the Web pages with math content. The search engine can look for the similar questions and offer the learner an option to inspect them as well as the corresponding answers. The collection of questions does not have to be comprehensive. As on the *Ask Dr Math* Web site (http://mathforum.org/), the archive may contain selected (by tutors) questions/answers. The user may or may not be satisfied with the provided options. The former means that the user found the system recommendations adequate and helpful enough (in this design model examples can be tagged so that the user can simply label one as helpful). This feature may help the knowledge base (KB) engine to increase reliability and usefulness of the help model and find out how satisfactory the proposition given by the system was. This feature was asked for

by the expert tutors as well. In the interviews the tutors emphasized that they receive too many repetitive questions and that for them having a pool of ready-made answers would also be useful. This is especially applicable in cases of help sites like *Math Nerds* (http://www.mathnerds.com/), whose policy is to provide hints rather than full solutions to the problems posed by the students.

If the user does not find the answers helpful enough, as the next step, they may be offered the list of questions that other students found useful in clarifying previous similar inquiries. This list can always be extended by the human intervention as part of the KB engine. The list can consist of the following:

> Students who asked similar questions also wanted to know:
> a) How to perform steps in...?
> b) What is given?
> c) How to start the question?

The existence of such lists would diminish the problem evident to many educators of students not being equipped with solid questioning techniques. In cases when a student provides some work, all these steps could be omitted since the tutor will probably be able to create a pretty good model of the student anyway.

2. *Development of online help bulletin boards with active memory.* Similar to the Semantic Web approach, each question could be tagged and a user modeled according to the type of questions asked (i.e., verification, definition, comparison, multiple, implicit, low specification, and other) (see [20]). The number of messages in previous inquiries may also reveal how motivated the user is. Knowing all this, the human tutor can count on the prolonged communication with a student or just a short (one time) interchange of messages.

Tutor helpfulness can also be monitored. Some peer tutoring sites like *Math2* (http://math2.org/) use this feature. The students there evaluate the answers, which consequently rank the tutors. It seems that some students acknowledge the tutors for the short response time rather than for the accuracy and appropriateness of answers. That motivates tutors to answer in haste, which may diminish the pedagogical value of the answers. Also, some users can attempt to game the system by answering their own questions and evaluating them favourably. However, on the large scale, given that this is voluntary help anyway and that evaluation can go by the person rather than by the question, this feature may be made more reliable. In addition, the tutors may be asked to comment on the question and explain why they accepted or refused to answer it. On *Math Nerds*, for example, the questions from the pre-defined areas get assigned to each tutor who may decide to return them to the common pool.

On the peer tutoring sites the computer agent can keep track of the number of questions/answers the user posted; the profile of the user consisting of the voluntarily provided information (maybe during the registration); and the user ranking in all of their roles. When taking a role of a student, the user should be encouraged to: attempt to answer the question without assistance; provide some relevant background information; read the other messages in the thread; and provide some feedback to tutors. When taking the role of a tutor, the user should be ranked (by the students) by the quality of contributions and (by the system) by the number of questions answered. The model of a tutor should keep a record of successful teaching attempts as well as unsuccessful ones. For each user the system should keep a record of the type of problems the user addressed in order to establish a better user model. This knowledge can be used to better match a tutor to a student.

According to the taxonomy of student-tutor communication (see [13]; [21]) incorporated in the system, both student and tutor work could be evaluated. Alternatively, the simplistic taxonomy developed for students' input in the ITS OMEGA system [36] can be applied to expert tutoring sites where a tutor can select a level from 0-5: (0) Incomplete-Wrong; (1) Incomplete-Partially Accurate; (2) Incomplete-Accurate; (3) Complete-Inaccurate; (4) Complete-Partially Accurate; (5) Complete-Correct. A level of (-1) can be reserved for the questions without work shown.

The problem is that such work may be given in chunks or increments. On expert tutoring sites, the majority of correspondence is one-off — a student writes a question and a tutor answers it — thus threads are relatively simple and short. On the peer tutoring sites, the threads can involve a number of tutors and be very difficult to summarize/evaluate. Also, such evaluation would not be very reliable because of the inexperience of the participants.

Benefits of Using Open User Model in Online Math Help

Opening the learner model in an online help forum and giving students an opportunity to revise it, means placing more responsibility on learners for creating their online image and ultimately for success of communication. In this type of environment participants' beliefs and motives are important parts of their image (see [37]). All participants should have an opportunity to inspect their models and add to them, since attitudes and feelings change in time. For example, the same learner can claim "I love mathematics," "Derivatives are difficult," and "I hate matrices." By putting those claims in perspective, one can follow the kind of emotional roller-coaster the person experiences while studying mathematics.

Bull et al. [5] confirm that the creation of semi-anonymous virtual identities in an attempt to provide open learner modeling is in general, good experience for the users. It is important that the users still have an option of posting and answering questions without the involvement of an agent and anonymously. In cases where users want to update/inspect their model they will have to register appropriately in order to get a personalized view. Only then will they be able to see in which way the system is adapted to them; what caused the adaptation; and how they can affect the adaptation.

Another important issue that needs to be addressed is the treatment/usage of learner's feedback. The previous study [21] looked for some evidence that the tutors' answers were appropriate enough so that the students were able to put them to use. This process has some similarity to what Tchetagni, Nkambou, and Bourdeau [35] call *reflection-on-action*. However, in the context of the study on online help the reflection was based on *the tutoring process*, rather than only on the *learner's work* (as in [35]). One of the conclusions in [21] was that online learners should be encouraged to elaborate on the helpfulness of the communication with the tutor(s). A "Thank you" note which students sometimes send to online tutors is valuable since it points to the closure of the threaded communication, but it contains no evidence of anything else. Only when the learner presents the revised, or completed work, or description of it, is there some evidence that the mathematics problem was really comprehended. This indication will not be sufficient to completely answer the questions "[W]hat happened exactly? Was it assimilation of knowledge, guessing of the right answer or an explicit insight on the skills to be learned and used?" ([35], p.48), but will be adequate to the level of dedication one can expect from the participants in these forums.

In order to come up with a model of the visitor to the help site, other measurable factors could be taken into account, like the threads visited and the number of the threads visited; as well as time spent in each session and per thread. Through this process, the system gains more insight into the visitor's behaviour and describes him/her as a *lurker* (if the person is mindlessly visiting links and not staying long enough to read), a *vicarious learner* (a person who opens and reads threads of similar discipline/topic) or an *active member* (a person that asks or answers questions). There may be some standards involved in labelling visitors as such. For example, for lurkers, no statistics would be collected. A vicarious learner's visits reflect popularity of the site as a learning resource and therefore would be of interest to the site owners. For active members, all the statistics and the model would be kept for as long as it makes sense and if they did not use the site for some time (longer than six months) their data could be erased. Since we are proposing a mixed model with a computer agent and human tutor, we believe that navigation patterns for active members can show their interests as well as to what extent they follow the agent's advice. Apparently the role of an agent would be to point learners to appropriate learning resources and the system will monitor whether the users visit these resources or ignore them completely. As a consequence the tutors will be informed that the student is not very much motivated to learn, or that the student is so insecure that s/he does not even try to do transfers between the suggested resources and a particular problem s/he has. Together with the track record of previous communication with the tutors, these facts will suggest the good tutoring strategy for that particular case, i.e., if the tutors should probe the student further, or provide only hints, or make an effort to be more helpful and thorough in their answers.

5. CONCLUSION

Online help sites are examples of groups of people gathered through the availability of Internet-based technological support and shared interest/need. As such, they fall somewhere between knowledge-based and social communities as defined by de Vries, Bloemen, and Roossink [7]. And although there already exist ITSs that can be used in an online environment, as well as efficient online help agents for specific domain, we see special educational and social value in online help communities based on human-to-human interaction. *Ask Dr Math* is an excellent example of the site that attracts diverse visitors – students and educators alike, as it provides a forum to discuss mathematics and pedagogy, and is also a rich resource center.

The peer tutoring sites are in fact communal networks. They have the same agenda and strong focus on satisfying their members' needs. Such communities are much more transparent and flexible than other online social structures. Their members have options to belong to more than one such community, to "move" between them according to their current interest, to take different roles in them (i.e. a tutor in one network can be a student in another) and to be at more than one place at the same time. When one site closes, its users migrate to another site, which makes it more difficult to properly track them down.

In this paper we discussed possibilities of improving mathematics online help sites through inclusion of computer agents of variable visibility. Given all the recent technological advances, the reader may be puzzled: "Whether the computer agents should take over answering mathematics questions online?" No matter how good ITSs become in what they are doing, there remains a fundamental value in online human-to-human networks. Computer technology can and should support human values, or as Schuler [29] writes:

> HCI (*Human-Computer-Interaction*) doesn't stop at the computer screen. What happens at the interface between the computer screen and a person in front of it is important, but it's just one link in a vast network of relationship between people and information and between people and people. Each link is a node in a rapidly expanding system of collective intelligence. (p.643, italics added)

Peer-to-peer networks provide strong social capital in terms of common knowledge, shared values, collective identity, roles and norms that are strong enough to help overcome dilemmas of collective action (people getting free-ride or not acting in fear that others may not follow) (p.653).

There are mathematics help sites where tutors get evaluated by the learners. This feedback, as we learned from the tutors, is the best way for them to find out if they have been helpful to the learner and to feel appreciated for volunteering their time and expertise. Honest feedback with acknowledgement maintains trust in large online interaction environments (Resnick et al., as given in [29]). Accordingly, the recommended open learner model can reinforce "good" student behavior in terms of (a) asking well-written and deep questions, (b) providing record of attempted work on the math problem for tutors to inspect, and (c) giving timely feedback to the tutors.

The involvement of a computer agent can increase the social capital of a help site. As a math verifier, it can minimize the number of unclear or fragmented messages. The agent can search for an appropriate answer in the existing archive before the human tutor gets involved, or it can look for the tutor with the matching skills and beliefs to the student's. By doing so, it will increase immediacy and decrease redundancy of the information sharing — the two major incentives for the satisfaction of the participants on the site.

6. REFERENCES

[1] Aleven, V., McLaren, B., Roll I., & Koedinger, K. (2006). "Towards Meta-cognitive Tutoring: A Model of Help-Seeking with a Cognitive Tutor", **International Journal of Artificial Intelligence in Education**, Vol. 16, No. 2, pp. 101-128.

[2] Balacheff, N., & Kaput, J. (1997). "Computer-Based Learning Environments in Mathematics". In A. Bishop (Ed.), **International Handbook of Mathematics Education**. Dordrecht: Kluwer Academic Publishers, pp. 469-501.

[3] Baylor A. L., & Kim Y. (2005). "Simulating Instructional Roles through Pedagogical Agents", **International Journal of Artificial Intelligence in Education**, Vol. 15, No. 2, pp. 95-115.

[4] Brousseau, G. (1997). **The theory of didactic situations**. Edited and translated by N. Balacheff, M. Cooper, R.

Sutherland & V. Warfield. Dordrecht: Kluwer Academic Publishers.

[5] Bull, S., Mangat, M., Mabbott, A., Abu Issa, A. S. & Marsh, J. (2005). "Reactions to Inspectable Learner Models: Seven Year Olds to University Students". **Proceedings of Workshop on Learner Modelling for Reflection**, AIED, pp. 1-10.

[6] Derry, S. J., & Potts, M. K. (1998). "How Tutors Model Students: A Study of Personal Constructs in Adaptive Tutoring", **American Educational Research Journal**, Vol. 35, No. 1, pp. 65-99.

[7] de Vries, S., Bloemen, P., & Roossink, L. (2000). "Online Knowledge Communities". In G. Davies & C. B. Owen (Eds.), **Proceedings of WebNet 2000 - World Conference on the WWW and Internet**, San Antonio, Texas, pp. 124-129.

[8] du Boulay, B., & Luckin, R. (2001). "Modelling Human Teaching Tactics and Strategies for Tutoring Systems", **International Journal of Artificial Intelligence in Education**, Vol. 12, No. 3, pp. 235-256.

[9] Engelbrecht, J. and Harding, A. (2005). "Teaching Undergraduate Mathematics on the Web. Part 1: Technologies and Taxonomy", **Educational Studies in Mathematics**, Vol. 58, No. 2, pp. 235–252.

[10] Engelbrecht J. & Harding A. (2005). "Teaching Undergraduate Mathematics on the Internet, Part 2: Attributes and Possibilities", **Educational Studies in Mathematics**, Vol. 58, No. 2, pp. 253–276.

[11] Fox, B. A. (1993). **The Human Tutorial Dialogue Project: Issues in the Design of Instructional Systems**. Hillsdale, NJ: Lawrence Erlbaum Associates, Inc.

[12] Garrison, D. R., Anderson, T., & Archer W. (2001). "Critical Thinking, Cognitive Presence, and Computer Conferencing in Distance Education", **The American Journal of Distance Education**, Vol. 15, No. 1, pp. 7-23.

[13] Graesser, A. C., Person, N. K., & Huber, J. (1992). "Mechanisms that Generate Questions". In T. Lauer, E. Peacock, & A. Graesser (Eds.), **Questions and Information Systems**, pp. 167-187, Hillsdale, NJ: Lawrence Erlbaum Associates, Inc.

[14] Hansen C., & McCalla, G. (2003). "Active Open Learner Modelling", **Workshop on Learner Modelling for Reflection**, Online Supplementary Proceedings, Vol. 5, pp. 248-257. Sidney, Australia: IJAIED.

[15] Karabenick, S. A. (1987). "Computer Conferencing: Its Impact on Academic Help Seeking". **Proceedings of the Second Guelph Symposium on Computer Conferencing**. Guelph, Ontario: University of Guelph, pp. 69-76.

[16] Kearsley, G., Hunter, B., & Furlong, M. (1992). **We teach with technology**. Wilsonville, OR: Franklin, Beedle, and Associates, Inc.

[17] Kodaganallur V., Weitz R. R., & Rosenthal D. (2005). "A Comparison of Model-Tracing and Constraint-Based Intelligent Tutoring Paradigms", **International Journal of Artificial Intelligence in Education**, Vol. 15, No. 2, pp. 117-144.

[18] LeJeune, N., & Richardson, K. (1998). "Learning Theories Applied to Web-based Instruction". Available at http://ouray.cudenver.edu/~nflejeun/doctoralweb/Courses/EPSY6710_Learning_Theory/ LearningTheories-WBI.htm

[19] Lepper, M. R., Woolverton, M., Mumme, D., & Gurtner, J. (1993). "Motivational Techniques of Expert Human Tutors: Lessons for the Design of Computer-Based Tutors". In P. Lajoie & S. J. Derry (Eds.), **Computers as Cognitive Tools**, pp. 75-105. Hillsdale, NJ: Lawrence Erlbaum Associates, Inc.

[20] Martinovic, D. (2004). "Communicating Mathematics Online-Comparison of Expert and Peer Tutoring". **Proceedings of the 24th Annual Conference of the North American Chapter of the International Group for the PME-NA**, Vol. 3, pp. 1465-1472.

[21] Martinovic, D. (2005). "What Are the Characteristics of Asynchronous Online Mathematics Help Environments and Do They Provide Conditions for Learning?" **Proceedings of the Workshop: Representing and Analyzing Collaborative Interactions**, pp. 32-39. Amsterdam, Holland: IJAIED.

[22] McArthur, D., Stasz, C., & Zmuidzinas, M. (1990). "Tutoring Techniques in Algebra", **Cognition and Instruction**, Vol. 7, pp. 197-244.

[23] Milech, D. K., Kirsner, G. R., & Waters, B. (1993). "Applications of Psychology to Computer-Based Tutoring Systems". **International Journal of Human-Computers Interaction**, Vol. 5, No. 1, pp. 23-40.

[24] Miner, R., & Topping, P. (2001). "Math on the Web: A Status Report". **JOMA: Journal of Online Mathematics and its Applications**, Vol. 1, No. 2.

[25] Noveck, B. (2000). "Paradoxical Partners: Electronic Communication & Electronic Democracy". In P. Ferdinand (Ed.), **The Internet Democracy and Democratization**, pp. 18-36. Ilford, Essex: Frank Cass.

[26] Putnam, R. (1987). "Structuring and Adjusting Content for Students: A Study of Live and Simulated Tutoring of Addition. **American Educational Research Journal**, Vol. 24, No. 1, pp. 13-28.

[27] Roblyer, M. D., Edwards, J., & Havriluk, M. A. (1997). **Integrating Educational Technology into Teaching**, Second Edition, Upper Saddle River, NJ: Prentice Hall Inc.

[28] Santoro, G. (1995). "What is Computer-Mediated Communication?" In Z. Berge & M. Collins (Eds.), **Computer-Mediated Communication and the Online Classroom: Overview and Perspectives**, pp. 11-27. Cresskill, New Jersey: Hampton Press.

[29] Schuler, D. (2002). "HCI Meets the Real World", In J. M. Caroll (Ed.), **Human-Computer Interaction in the New Millennium**. ACM Press.

[30] Self, J. (1990). "Theoretical Foundations for Intelligent Tutoring Systems". **Journal of Artificial Intelligence in Education**, Vol. 1, No. 4, pp. 3-14.

[31] Self, J. (1990a). "Bypassing the Intractable Problem of Student Modeling". In C. Frasson & G. Gauthier (Eds.), **Intelligent Tutoring Systems: At the Crossroads of Artificial Intelligence and Education**, pp. 107-123. Norwood, N.J.: Ablex.

[32] Shneiderman, B. (2001). Creating Creativity: User Interfaces for Supporting Innovation. **ACM Transactions on Computer-Human Interaction**, Vol. 7, No. 1, pp. 114-138. Reprinted in Human-Computer Interaction in the Millennium, Addison-Wesley, Reading, MA.

[33] Schoenfeld, A. H. (1992). "Learning to Think Mathematically: Problem Solving, Metacognition, and Sense-Making in Mathematics". In D. Grouws (Ed.), **Handbook for Research on Mathematics Teaching and Learning**, pp. 334-370. New York: Macmillan.

[34] Spiers, G. F. (1996). An Analogical Reasoning Based Mathematics Tutoring System. Unpublished doctoral dissertation, Computing Department Lancaster University, Lancaster, Great Britain. Retrieved August 30, 2002, from ftp://ftp.comp.lancs.ac.uk/pub/reports/ThesisGSp.ps.Z

[35] Tchetagni, J., Nkambou, R. & Bourdeau, J. (2005). "Supporting Student Reflection in an Intelligent Tutoring System for Logic Programming", **Learner Modelling for Reflection Workshop**, pp. 42-51. Amsterdam, Holland: IJAIED.

[36] Tsovaltzi, D. & Fiedler, A. (2003). "An Approach to Facilitating Reflection in a Mathematics Tutoring System". In S. Bull, P. Brna & V. Dimitrova (Eds.). **Learner Modelling for Reflection**, AIED2003 Supplementary Proceedings, Vol. 5, pp. 278-287. Sidney, Australia: IJAIED.

[37] Zapata-Rivera, J. D. & Greer, J. E. (2003). "Analysing Student Reflection in the Learning Game". In S. Bull, P. Brna & V. Dimitrova (Eds.). **Learner Modelling for Reflection**, AIED2003 Supplementary Proceedings, Vol. 5, pp. 288-298.

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